INVESTIGATION OF PITOT'S TUBES AS A WATERMETER

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INVESTIGATION OF PITOT'S TUBES
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Contents.

List of Photographic Plates.

List of Drawings.

Introduction.

Throughout the world there have been installed many hydraulic power plants, and the study of the hydraulic machinary at this present stage cannot be too much valued. Almost all modern plants seem to be equipped with instruments and appliances for obtaining output on the electrical end, but there are comparatively a few that are provided with any means of determining the hydraulic input.

Difficulties of measuring the discharge of water have been encountered by many an engineer, but a long series of experiments of industrious experts resulted in discovering several available methods.

To be sure, the most exact method of measuring discharge is to weigh the water actually for a certain period of time, but this method is condemned in practice, simply because inconvenience in its

installation and waste of time and labor in its procedure is unavoidable.

The Venturi meter is now accepted as a fair means of carrying out the purpose in question, but its initial cost and difficulty in installment after the plant is once in operation prevent it from being adopted generally.

The use of various forms of weirs are advocated by many engineers and this method is fairly satisfactory, provided that the head over the weir can be kept constant.

Still another method which has been proposed was very widely used and that is the use of nozzles, by careful calibration of which discharge of water can measured with some degree of accuracy.

The Pitot's tube is also used in gauging the flow of water through channels and pipes. The prin-

ciple involved is comparatively simple, being direct application of the theorem of Torricelli. The chief advantage of this method lies in the cheapness of the instrument itself and ease in its installation. The tube in its slight modified form can be used to measure the flow of fluids other than water. Several authorities have worked along this line, and some of their experiments are exhaustive, but there is still room enough for investigation of flow of water through pipes and channels.

Object.

The object of this thesis was originally to investigate the applications of the Pitot's tubes for measuring the velocity of water flowing through small pipes. The head of water causing the flow is not to be very large. The tubes are to be screwed into tapped holes on pipes, the flow of water through which is to be determined. As the head is low, no contrivance is necessary to provide a means to strengthen that part whcih is weakened through tapped holes.

As stated before, the first object sought was to determine the adoptability of the tubes under the specified conditions, but after several runs were made, it was found necessary to confine the subject to the question: "Is it possible to have unfluctuating static head after all"?

This narrowing of the subject was inevitable, as it was believed that the size of tubes might be too large for the size of pipes that were considered. With this object in view, investigations were made, all of which are described later.

Previous Investigations.

Before any attempt is made in the investigation for the flow of water, it is necessary to see what others have done along the line of the Pitot tube. Many authorities and experts made a research covering the field, in which we are interested at present. Of those the following are the most important ones.

Prof. A. H. Gibson of the University College, Dundee undertook an investigation for the flow of water with a view to determine the loss of head through friction in pipes of various forms and sizes, and he gave his results in the form of curves. He showed how the velocities of water vary as the distance from the walls. To measure the velocities he made use of the Pitot tubes and he showed that they were very satisfactory.

Mr. E. S. Cole made an elaborate test on the Pitometer. His experiment was to calibrate the meter against a weir. He found out that there was a dicrepancy of from 30% to 50% between the total pumpage and the total Pitometer readings. He did not give his opinion for this discrepancy, but it is believed that the errors were not due to the defects in the Pitometer itself. He published his research in the December, 1907 issue of the Journal of Franklin Institute.

The "American Machinist", March 9, 1905, publishes efforts of Mr. W. M. White. His method is like that of Mr. Cole: the standard weir notch was used for the calibration of Pitot's tubes. This time, his results of the readings of differential head practically agreed with values calculated from sevaral formulae pertaining to the flow of water in

pipes and over weirs.

This Mr. W. M. White had read, prior to his previous test just mentioned, a paper before the Association of Engineering Societies. In this paper, he dicussed several of his own experiments on the subject and concluded:

1. That only pressure openings which give the true static head of water should be used in connection with the point of a Pitot's tube. That is to say that only tubes which have unity as their coefficient should be used.

2. That Pitot's tubes whose constants are unity in open canal ratings will remain unity, whatever the pressure of the liquid may be.

Messrs. Williams, Hubbell and Fenkell tried a series of tests on Pitot's tubes both in closed and open flow. Their efforts were rewarded with the

invention of the oil differential gauge, by which it is possible to observe difference in heads in closed conduits under pressure with as great a degree of precision as attainable in open conduits with the hook gauge. They also determined coefficients of several Pitot's tubes on hand, and concluded that the dragging of tubes in still water did not conform to cases of stationary tubes in moving water.

The investigation of Messrs. Lawrence and Braunworth in the hydraulic laboratory of Cornell University shows that the Pitot's tubes are suited for the measurement of flow under low heads.

Messrs. James E. Boyd and Horace Judd made a series of experiments with various forms of Pitot's tubes, but unfortunately their efforts proved unsatisfactory. They concluded that failures were

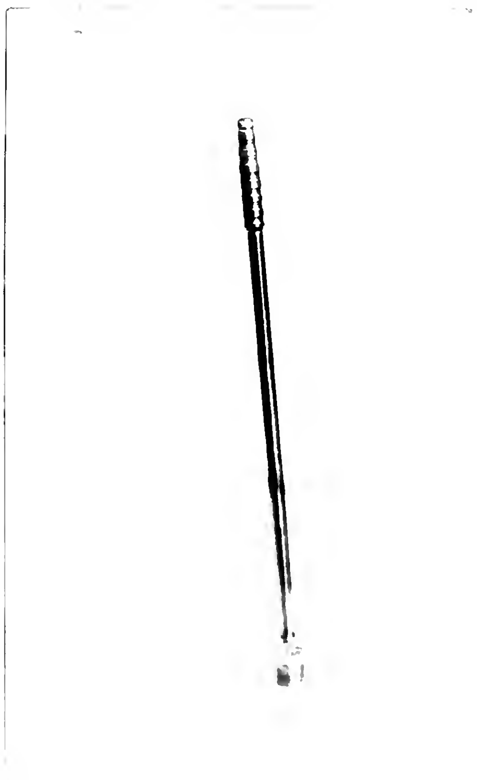
due to not obtaining true static pressure, rather than to any error in the tube itself.

Description of Apparatus.

The main feature of the apparatus is, of course, Pitot's tubes. The tubes employed are two in number: one for the static head, and the other for the dynamic head.

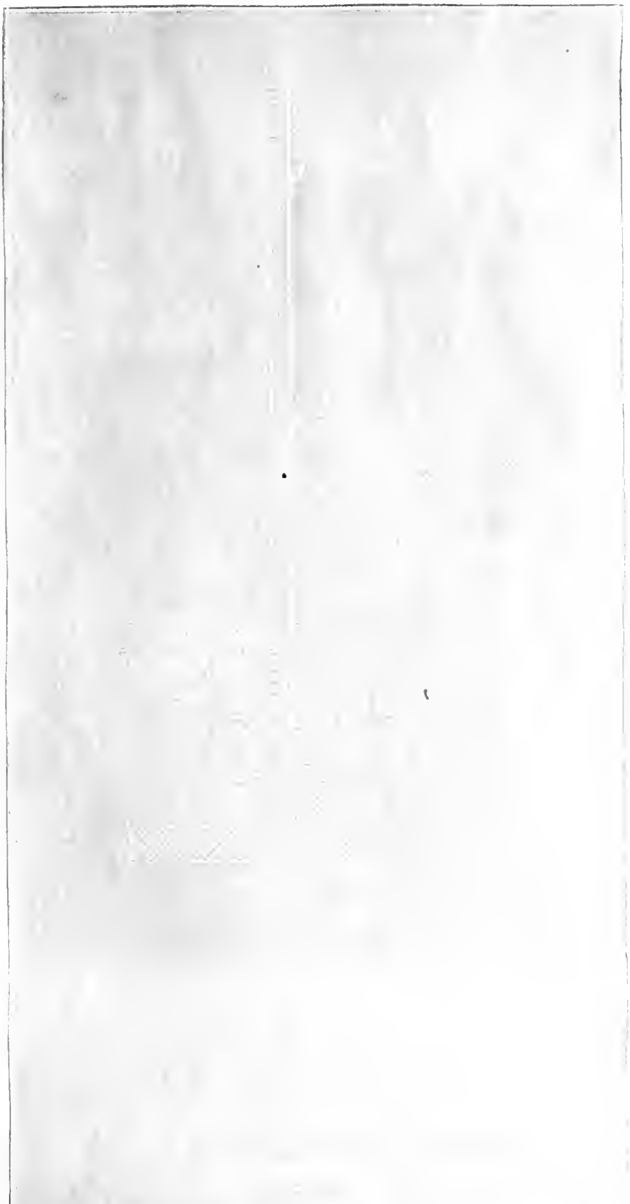
The static tube is simply a brass tube to which a one-eighth inch brass pipe-plug is brazed. One end of the tube is flush with that of the plug. A conical ring is attached to the other end of the tube for the purpose of facillitating its connection with rubber tubing. The picture of the static tube is shown in the Plate I, and its sketch is given in the Figure 1 with dimensions.

The dynamic tube, as shown in the Figure II, is simply a tube bent at a right angle, so that,



upon insertion in the pipe, its open end can be turned in such a manner as to receive the static and velocity pressures. As the dynamic tube should be moved across the diameter of the pipe, a brass stuffing box with a gland of the same material is provided as shown in the sketch. A conical ring is also attached to the end of this tube for connection with rubber tubing, as with the static tube. The Plate II is the picture of this dynamic tube.

These tubes are screwed into the tapped holes in the pipe, through which the rate of flow of water is wanted, but the utmost care must be taken in every case to keep the end of the static tube flush with the inner wall of the piping.



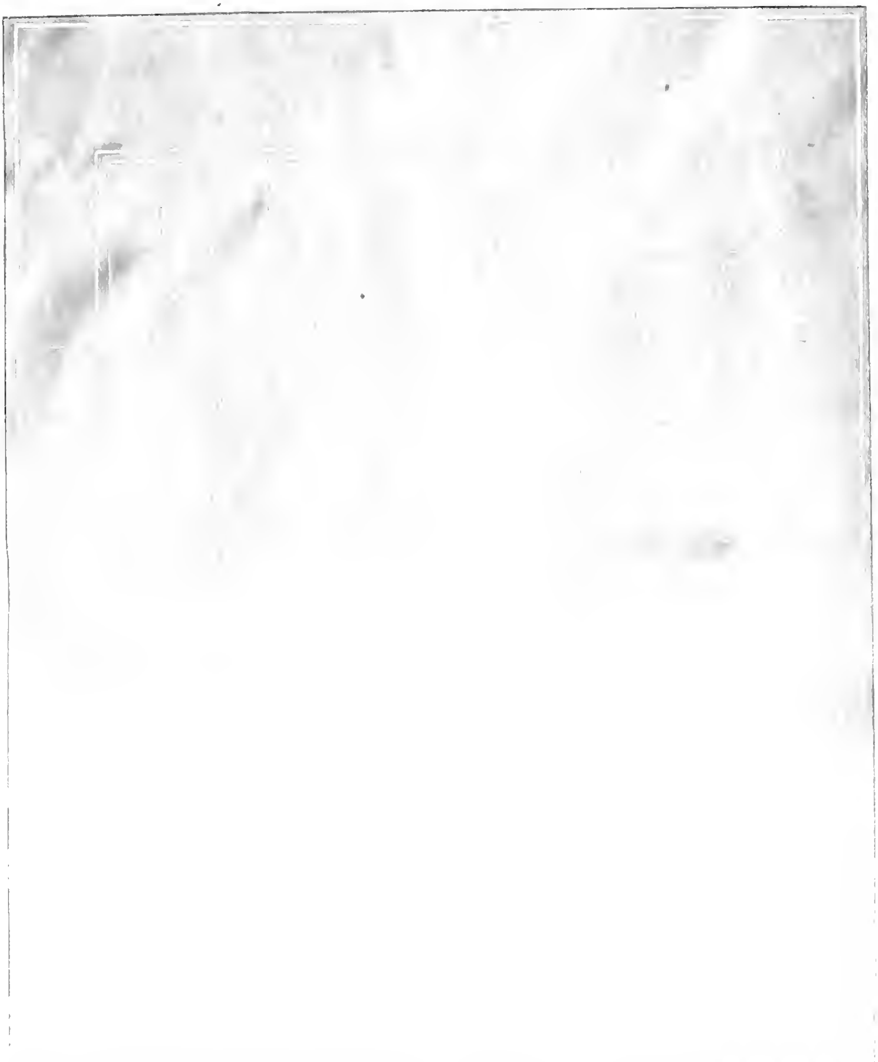
Both the static and dynamic tubes were made at the Armour Institute of Technology.

Water is supplied by means of a centrifugal pump manufactured by the Dayton Hydraulic Machinary Company of Dayton, Ohio. The maximum capacity of the pump is 390 gallons per minute at the lift of twenty-five feet. The diameter of the impeller is seventeen inches. Six curved blades are provided in the impeller for guiding the flow of water.

Water is sucked from the sump of the hydraulic laboratory at the Armour institute of Technology. The centre of the impeller is feet above the level of water in the sump. The suction is effected through a four inch ordinary cast iron pipe.

The discharge pipe is of galvanized iron and five inches in diameter. Water is discharged into a tank provided with an overfall weir.

The tank is seven feet six inches long, and five feet six inches wide. Its depth is three feet two inches. A twelve inch rectangular weir notch is cut on the side, and the overflow is led back into the sump again. Thus, the same water is used over and over again. The tank is equipped with a series of baffle plates as shown in the Figure III. The plates serve to prevent disturbances which is unavoidable in the case of a quantity of water discharged. A tank has a hole in the bottom, so that water may be emptied through it.



A hook gauge is employed in obtaining the head over the weir, which was calibrated before. It is equipped with electric connection for the purpose of getting the zero reading.

At the later stage of tests, a weighing tank is used instead of the hook gauge. The tank has a tare weight of 355 pounds and its capacity is about eighteen hundred pounds of water. The scale has a set of weights and can be read correct to a quarter of a pound.

The pump is motor driven. The motor is of the direct current interpole type and is rated at 10 H.P. Its voltage is from 110 volts to 125 volts, its normal amperage being 76. A starting box built by the Cutler Hammer Manufacturing Company. The

starter has several notches for changing the speed of the motor.

For supporting glass tubes the use is made of a wooden board. The tubes are secured to it with nails and string.

Method of Procedure.

The first preliminary run was made on Jan. 24th, 1912. The arrangement of the apparatus is shown in Fig. 3. At the point A on the delivery pipe, both the static and dynamic tubes were inserted. Glass tubes for measuring heads were tied by means of string to the five-inch galvanized iron pipe, connections being made to the Pitot's tubes through rubber tubing.

A 10 H.P. interpole motor was connected by means of belt to the ten inch pulley of the centrifugal pump.

After necessary priming was done, the pump was started and water was allowed to flow over the weir already described. The weir had already

been calibrated carefully, so that the rate of flow of water could be obtained by reading the head over it.

For a few hours the pump was allowed to run, and the head over the weir notch was read occasionally. It was then found that the head remained constant during the period, and everything seemed to be running smoothly. Static head appeared constant, and velocity head was steady.

When it was attempted to obtain a running log, it was found that something must be done to prevent the fluctuation; for, the static head ceased to be steady, the maximum difference reaching to eight inches.

The cause of this sudden fluctuation is un-

known yet, but this much was then certain that it was not due to the irregular supply of water; for, the motor kept the speed of 1400 revolutions per minute and the head over the weir remained at five hundredths of a foot.

The rest of the day was spent in examining leakage and sttopage in the entire arrangemmnt, but no fault could be found. This necessitated abandonment of the present arrangement, and the only other way that suggested itself was to insert the tubes on the suction side. The test was, accordingly, discontinued for the day.

The second run was conducted on Jan. 31st, 1912. The apparatus was altered materially, but the Pitot's tubes were placed on the suction side

at the point B in Fig. 3. The procedure was like that of the first run, but this time fluctuation of both heads was so great that the scheme was given up immediately.

Another test was tried on Feb. 14th, 1912. Owing to the failures of the two previous experiments, a Peclet's differential draft gauge was substituted. The gauge was filled with metalic mercury, the object being to curtail fluctuation. The fluctuation was cut down a little but it was big enough to render experimentation impossible. Under the circumstance it was necessary to discontinue the test.

On Feb. 24th, 1912, another unsuccessful attempt was made and its result was that we should

find another means for rating of the flow. The Most urgent problem on hand became, "Can we obtain unfluctuating static head after all"?

The test was laid aside for a few weeks, and it was in the beginning of April that it was resumed. The conclusion of preceding tests excluded the direct use of the centrifugal pump. The purturbance and eddy caused by suction and delivery were found too violent to admit of such a procedure.

The next method resorted to was the use of the weir tank, of which a mention has been made occasionally. It should be noted that the weir notch was employed simply for taking care of the overflow and keeping a constant head. The overflow was not used

for the measuring purpose at all and led to the sump.

An inch and a quarter pipe was provided for connecting the bottom of the weir tank with a weighing tank as shown in Fig. 5. An auxiliary pipe made of galvanized iron was employed in conducting water to the sump when the tank was not in use.

In obtaining the differential heads, glass tubing was again employed and their readings were taken with a scale. The glass tubes were supported side by side vetically, being secured to a wooden board.

After these preparations were done, another experiment was begun on April 17th. The centrifu-

gal pump was started again, but it was so controlled that the head over the weir was kept at 0.05 ft.

Unpulsating static head was obtained as long as the dynamic tube was left alone, but the minute it was moved a fraction of an inch the static head seemed to jump six or seven inches. This fluctuation was not accounted for, but it was assumed to be due partly to non-smoothness of the inside of the piping and partly to the presence of eddy current formed by entering water from the tank.

On the next day all the burrs which could be found inside the pipe was filed off with a round file to ensure the smooth inner wall. To prevent water from forming eddy current, a cross made of

tin plate was introduced at the entrance to the pipe line. With these equippments the test was made over again, but nothing was improved at all. Fluctuation was as large as it had been and any reading of value could scarcely be taken.

Another run was made on April 24th. The arrangement of the apparatus was the as that of the previous one, but a slightly greater head was used. The head over the weir was kept at 0.3 ft., and the run was repeated. The attempt was unsuccessful as before.

Another attempt was made on May 1st. This time it was thought best, if possible, to change relative positions of the static and dynamic tubes. To accomplish this end, several holes were tapped

along the pipe, so that the tubes could be inserted wherever it was chosen, unused taps being stopped with pipe plugs.

Several trials with different positions of the tubes were made, but nothing was gained in this way. They met the same fate of their predecessors.

Thus, almost all available methods had failed. The only way that could be done was to use longer piping. The piping used before had two couplings, two elbows, three nipples and one gate valve beside the main pipe. The next arrangement did away with two couplings and two nipples. The use of a longer pipe enabled this.

On May 15th this method was tried and it was

found to be a failure again.

For several days unfruitful attempts were made to obtain unpulsating static head. In each trial a slight change in conditions was made, but finally the experiment was given up.

Conclusion.

From the results of the fore-going expriments, it seems to us that the Pitot's tubes cease to be useful unless some means of obtaining unfluctuating static head is found. Especially that is the case when the tubes are comparatively large, so that there is some possibility of affecting the flow by inserting them.

The whole thing lies in the point that the discharge is a direct function of the differential head. If this head can not be depended upon, the adoptability of the Pitot's tubes as watermeter is not very promising.

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some more convenient way of gauging the rate of flow of water in the pipe.

It is unfortunate to note that this test met the same fate that experiments of Messrs. Boyd and Judd had met, although the tests were made under different conditions. Let us hope and endeavor to overcome the afore-said difficulties, and some day we shall be able to count on the Pitot's tubes.